The Arbitrage System on Decentralized Exchanges

Naratorn Boonpeam, Warodom Werapun, and Tanakorn Karode
College of Computing
Prince of Songkla University
Phuket, Thailand
s6330622002@phuket.psu.ac.th, warodom.w@psu.ac.th, s6230622001@phuket.psu.ac.th

***Abstract*—Cryptocurrencies are in great demand in society. The number of beginners on the cryptocurrency market increases every day. Most of them only focus on a high return on the cryptocurrency investment. However, they do not aware of the high risk from its volatility. Trading is the most popular way to invest with digital currencies due to its potential returns. The cryptocurrency exchange requires a high learning curve for beginners. There exists a strategy to minimize risk in the cryptocurrency investment called "arbitrage". It exploits the market inefficiency to discover a profitable method. This strategy has been investigated in traditional markets like stock markets. Furthermore, some researchers studied arbitrage on general exchange platforms that are operated by companies. However, to the best of our knowledge, there is no research works on arbitrage in the Decentralized Exchange (DEX). The DEX recently emerged with a huge amount of trading volume and profits. The high profit is along with the high risk. Thus, risk-reducing in the cryptocurrency investment is a crucial topic. We demonstrate arbitrage strategy on DEX. The strategy used in this work is to invest an amount of Ether and receive a higher return in each row. The market inefficiency on the current DEX platforms is searched by using an automatic method. We further investigate important factors, which should be considered for profit-maximizing in DEX arbitrage.**

Keywords—cryptocurrency, profitability, arbitrage, decentralized finance

I. INTRODUCTION

Cryptocurrency trading is the main source of digital currency investment. People participate in the market more because it provides a high return. However, the main tradeoff of the cryptocurrency market is volatility. It requires many fundamentals to keep investors maintain their profits in long term. New investors ignore the fundamental learning because it requires much effort and time. Since they lack essential knowledge about the investment, most of them lose much cost from the digital currency investment. Some people may panic according to the high amount of cost they waste. As reported on many sources[1,2], there are people suicide because of stress from losing investment cost. Thus, investigating and introducing lower risk strategies are crucial works for researchers. There are prior research works studied about controlling high risk on a Centralized Exchange (CEX) [1], [2]. Those works determined the arbitrage system on CEX, which is popular today. However, the innovation like Decentralized Exchange (DEX), which emerged with higher returns and risks, has not yet been researched.

In this work, we study a risk-free strategy called "Arbitrage" on DEX. We implement and propose the market inefficient searching tool. The tool that automatically finds the maximum profit route of listed tokens. A couple of popular DEX platforms are selected and applied with the proposed tool to find the best profit platform in each row. According to the experiment result, the proposed tool can help to search the maximum profit route within a short time. We then further investigate essential factors that affect profit from arbitrage. The results indicate that factors such as market condition, and port size much affect profits. More importantly, increasing a port size does not always provide more profits. Additionally, a transaction fee does not much impact incomes.

The rest of this paper is organized as follows. Information about CEX, DEX, and arbitrage is researched and discussed in Section II. In section III, we illustrate the research methodology and proposed framework. The proposed framework is tested in Section IV. The experiment results are also presented in this section. Eventually, we conclude the work on the last section.

II. LITERATURE REVIEW

A. Cryptocurrency Exchanges

Cryptocurrency exchange platforms provide investors with profit-making on digital cash. Currently, most investors use exchange platforms that are operated by companies. These CEX platforms maintain user wallets and provide customer support service for ease of use. This causes most investors to generally involve in CEX. They can make a large number of profits compared to stock trading. However, the volatility of cryptocurrency produces high risk. There is prior research about risk management for cryptocurrency trading [3]. In recent years, there is an innovation in the blockchain world that has the potential to generate a huge amount of profits in a short time. It is called "Decentralized Finance (DeFi) [4]". Uniswap [5] is a popular application in DeFi. It is a cryptocurrency market that is not controlled by a central authority and its token price depends on actual trades. Uniswap can be categorized as a Decentralized Exchange (DEX). Popular examples of DEX platforms involve in this work comprise Kyber network, 1inch, Bancor, Kulap. Even though DEX returns higher profits than CEX, it also has a higher risk. However, there is research that provides guidelines for investing in DEX. Most of them focus on cryptocurrency trading, which still produces high risk. In this work, we investigate an investing strategy that can minimize risk on DEX. Arbitrage is an interesting strategy since it might suitable for the market inefficiency of DEX.

B. Arbitrage

A strategy to generate a profit by exploiting some information that is not presented can be classified as an arbitrage. Authors in [6], [7] provided crucial information about cryptocurrency market conditions. They stated that the digital currency market provides many recurrent arbitrage

[1] https://www.forbes.com/sites/sergeiklebnikov/2020/06/17/20-year-old-robinhood-customer-dies-by-suicide-after-seeing-a-730000-negative-balance
[2] https://www.sanook.com/news/7939630/

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opportunities in exchanges. The cross-exchange arbitrage was investigated. From their experiment, the price deviations are much larger across countries and smaller between tokens. The price deviations increase when the bitcoin price is much raised. Exchanges in each country have a different deviation of prices. The authors decomposed the signed volume on each exchange. Their proposed framework can explain arbitrage spread between exchanges.

Statistical arbitrage is a technique to find an opportunity for profitable trading. It has been utilized in almost every market. Prior research studied statistical arbitrage on CEX [8]. The authors of that work applied machine learning to analyze market price. Consequently, initial machine-learning-based statistical arbitrage strategies have emerged in the U.S. It supported space on minute-binned data to predict whether a coin outperforms the cross-sectional median of all 40 coins.

Lindsay X. Lin investigated the important benefits of DEXes in many aspects [9]. People do not need to trust a central organization. They can invest and manage their own assets on the decentralized services. Any tokens can be listed on DEXes without permission. An example of useful tokens that are not listed on CEX is PSU COIN [10], which incentivizes student activities. Listing PSU COIN on DEX raises its value and provides benefits to participants including students, the university, and associated organizations. More token pairs available on DEXes produce many opportunities for profit-generating. His work initiates the idea of DEX investment studies. We gather techniques from traditional investments and apply them to DEX. This work demonstrates the DEX arbitrage strategy. The methodology and framework are discussed in the next section.

III. METHODOLOGY AND FRAMEWORK

The procedure of an arbitrage system in this work is to start investing with a token and end with more amount of the same token in a row. This strategy relies on market inefficiency, which cannot be easily extracted in a stable market like CEX. In the early phase of a market, there are more opportunities for the arbitrage strategy to make profits. In this work, we examine arbitrage with manual and automatic methods.

A. Arbitrage Procedures

We conduct the arbitrage strategy as following procedures:

(1) Define the base token. In this work, we use ETH as the base token. List all middle tokens and platforms to use.

(2) On a platform, convert the base token into another token and convert it back into the base token. In this step, only one token is used as a middle route in each row for simplicity.

(3) Increase number of tokens in the middle route.

(4) Apply the above steps on other platforms and compare the profits.

At the beginning of the research, the procedures are applied to the manual method. It is not feasible to manually find the best profit route and platform according to the experiment result presented in the next section. As a result, we decide to implement an automatic arbitrage system to improve searchability.

B. Proposed Framework

The automatic arbitrage system applies the procedures by adapting the state space-search algorithm [11]. It is capable to search every possible route of the listed tokens and find the maximum profit route. The system notation can be determined as (1). Let $R(n_i)$ denotes the maximum profit route. The current profit is calculated by $r[n_i, a]$. The maximum profit routes of the remaining tokens are calculated on $R(n_j)$.

$$R(n_i) = \max_a(\{r[n_i, a], R(n_j)\}) \quad (1)$$

The optimized route searching tool is implemented by adapting state-space search algorithm as (1). The pseudo-code of the proposed framework is illustrated in Algorithm 1. The function needs 3 input arguments: token list (T), price graph (P), and the current route (n). The token list can be manually defined by a user. The price graph is constructed by using the prices of all token pairs. The prices of token pairs are retrieved from the selected platform. The initial current route is defined as an empty set. The algorithm starts calculating profit of each route by using the *get_profit(n)* function, which receives a route (n) as a parameter and returns the profit in Ether. The remaining route revenues are calculated with a recursive call of the searching function. The profit of the current route is then compared to the remaining route returns. Finally, the maximum price route (p) is summarized when all possible routes are calculated.

Algorithm 1: Maximum Profit Route Searching (R)

Input: $T(token\ list), P(price\ graph), n(current\ route)$
  for $i = 1, \dots, T$
    $r = get\_profit(n + i)$
    for $j = 1, \dots, P[i]$
      $p = \max(r, R(T, P, n_j))$
return p

The algorithm is used to search the maximum price route on a platform. We search the optimal routes in each platform and compare each other. The system can improve the searchability for maximum profit token routes. We evaluate the framework in the next section. Furthermore, important factors of arbitrage are studied by utilizing the proposed system.

IV. SYSTEM PERFORMANCE

Trading profits will be compared on different token routes from within an exchange and among well-known exchanges. Several factors such as transaction fee, gas price, market environment are taken into account. Eventually, the experiment results are presented.

A. Arbitrage on different token routes within an exchange

We first trade on a token route by selecting from different routes from Uniswap (DEX). We manually choose popular listed tokens, ETH, DAI, USDT, MKR, and BAND, to be in token routes. Three tokens routes are 1) "*ETH → DAI → USDT → ETH*", 2) "*ETH → DAI → MKR → ETH*" and 3) "*ETH → DAI → BAND → ETH*" denoted as token route 1, 2 and 3 respectively as illustrated in Fig 1. The trading results from three token routes reveal that investors lose profit from these arbitrages. Investors face the problem of selecting token routes in order to win the market since finding the high-profit token routes is one searching problem that is not easy to be done by manually selecting.

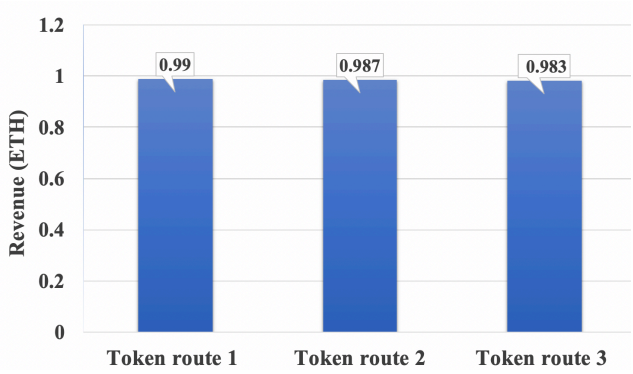

Fig. 1. Trading profits on different token routes within Uniswap

B. *Arbitrage on the same token route among different exchanges*

Trading tokens without knowing the price and related factors in a token route is a high risk of loss. Selecting token routes are calculated using *Algorithm 1* which is implemented as a tool to rapidly retrieve the price for investors. The interested token route result is "*ETH → MKR → OMG → USDT → ETH*". This token route is traded on well-known exchanges as shown in Fig 2. We found that 1Inch (DEX) offers arbitrage opportunities to gain revenues for investors while other exchanges still lose profits from the experiment.

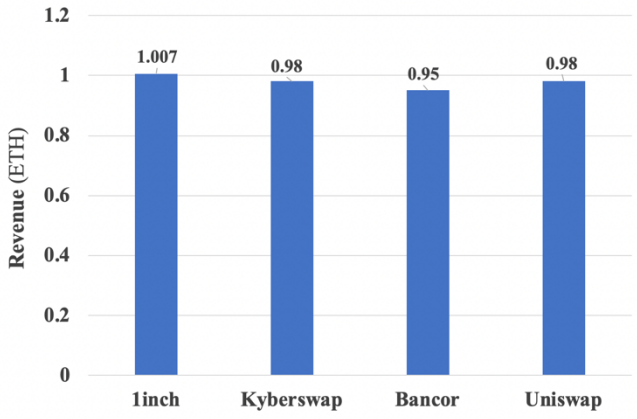

Fig. 2. Trading profits same token routes within different exchange

C. *Trading environment*

Several factors are considered to gain more profits in this environment.

1) Portion size: 1 ETH is the token amount that uses to trade in the exchange. In addition, investors trade larger portion sizes e.g., 10 ETH, 100 ETH or more, to have more profits. However, token pair price is automatically adjusted based on the demand/supply, as called automated market maker (AMM), in the market. The large portion size does not gain more profits. On the other hand, it makes investors lose their revenues as shown in Fig 3.

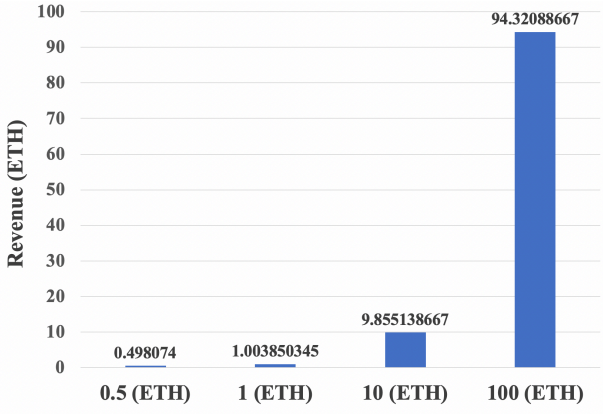

Fig. 3. Trading revenue in different portion sizes

2) Transaction fee: profits from trading may be affected by the transaction fee. The transaction fee is calculated from the gas price and the gas used value. Table I illustrates the aggregated values of costs from many transactions. The trading result describes that the transaction fee is less impact on the profits when it is compared with high volume of token exchanging.

TABLE I. EXCHANGE TRANSACTION FEES

Transaction fee	1inch	Kyber swap	Bancor	Uniswap
Avg	0.112	0.057	0.016	0.98
Max	0.338	0.214	0.059	0.986
Min	0.020	0.0156	0.0050	0.98
S.D.	0.097	0.040	0.0112	0.00090

3) Other considerations: token exchange price is one important factor to gain more profits since 1inch (DEX) shows that although it requires the highest transaction fee, it offers profits more than other exchanges. Price impact (or price slippage) is one factor to decide the trading result. If an exchange can provide a large liquidity pool, the price impact will be decreased. The liquidity fee does not include in the transaction fee. However, total revenues are calculated from all factors. The too low volume of token exchanging is difficult to gain profits due to a fixed cost of the transaction fee. In contrast, the too high volume of token exchanging is not recommended because of price slippage and the percentage of exchange liquidity fees. The heart of arbitrage is to find a suitable volume (sweet-spot) that gains more profits.

V. CONCLUSION AND FUTURE WORK

We proposed the arbitrage system on decentralized exchanges. The state-space search algorithm is adapted and used for rapidly retrieving token prices. The contribution of this work is not only to propose the arbitrage system on

decentralized exchanges but also to reveal the profits from trading the token route regarding on different decentralized exchanges. Moreover, related factors are discussed. 1inch (DEX) offers the best profits over other exchanges. Our proposed solution can be applied to several platforms. In future work, the profit percentage needs to be revised for other investments (e.g., staking, yield farming, etc.). If the profit percentage of the arbitrage system is closed to other investments, then several factors, such as risk, time to process, time to invest, price slippage, etc., should be considered regarding to the situation.

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